

Requirements for Global Precipitation Measurement

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Abstract—The measurement of precipitation on a global basis has many scientific and societal benefits. The National Aeronautics and Space Administration's (NASA's) Tropical Rainfall Measuring Mission (TRMM), developed in cooperation with the National Space Development Agency (NASDA) of Japan, was launched in 1997, and is widely viewed as a highly successful mission. TRMM has successfully addressed many science issues, has identified areas relating to precipitation where additional research is required, and has also demonstrated the value of precipitation measurements to other disciplines, including hydrology and weather forecasting. In response to substantial interest in precipitation measurement, NASA has established a Project Office to begin planning for Global Precipitation Measurement (GPM). This paper will provide a brief overview of the needs for precipitation measurement, identify the top-level requirements, and provide details concerning the spacecraft and instruments that comprise the space segment of the concept mission.

INTRODUCTION

The measurement of precipitation on a near-global basis has many scientific and societal benefits. These benefits include increased scientific understanding of the processes affecting global climate change, improved measurements of rainfall and hydrological processes, improvements in weather forecasting, and better definitions of severe storms, including the forecast of both the storm's magnitude and its ground track. Global Precipitation Measurement (GPM) is completing the process of defining its science objectives, the measurements that are required for the accomplishment of those objectives, the structure of the program, and the definition of the required instrumentation.

THE TROPICAL RAINFALL MEASURING MISSION

The Tropical Rainfall Measuring Mission (TRMM) provides an excellent foundation upon which to begin the planning for GPM. TRMM was a collaborative effort between the National

Aeronautics and Space Administration (NASA) of the United States and the National Space Development Agency (NASDA) of Japan. It was, and continues to be, a wonderfully successful mission. TRMM makes measurements of clouds and rainfall from space using the Ku-Band Precipitation Radar (PR) and the multi-channel TRMM Microwave Imager (TMI). It has satisfied its scientific objectives of making multi-year measurements of tropical rainfall, provided increased understanding of how the interactions between sea, air and land masses produce changes in global rainfall and climate, and helped to improve modeling of tropical rainfall processes and their influence on global circulation. TRMM also helped to test, evaluate and validate satellite rainfall measurement techniques. TRMM has thus greatly expanded the scientific understanding of precipitation, identified areas for further research, demonstrated the value of rainfall measurements to the weather community, and validated an approach for making precipitation measurements.

As the use and applications of the scientific data collected by TRMM has matured, users of this data have identified new areas for investigation, and new applications for the measurements. There is a desire to extend measurement coverage to a near-global basis. There is a desire to increase the scientific knowledge of rainfall processes through better understanding of cloud structure, including their horizontal and vertical components and micro-physical elements. There is a desire to increase measurement sampling sufficiently to reduce uncertainty in short-term rainfall accumulations. And finally, there is the desire to apply the benefits of this scientific knowledge for the betterment of society. The development of a new program to address these interests has received strong, unified support. NASA has responded by directing the Goddard Space Flight Center (GSFC) to establish a Project Formulation Office for GPM.

GPM PROJECT FORMULATION

The GPM Project Formulation Office is responsible for developing, planning, and managing a mission that is responsive to the interests identified above. These interests have coalesced into three overarching science objectives for GPM: (1) Provide improved climate observations and prediction, (2) Improve the accuracy of precipitation forecasts and weather prediction, and (3) Provide improved understanding of the global water cycle, including flood and fresh water resource prediction. As was done for TRMM, NASA Headquarters has begun the process of formalizing a cooperative agreement with NASDA for GPM. As part of this agreement NASDA will provide a Dual-frequency Precipitation Radar (DPR), a launch vehicle, and launch services. NASA will provide spacecraft, microwave radiometers, satellite operations, communications, ground data processing, and ground validation. NASA Headquarters has identified the financial resources available and has provided guidance to GSFC in areas that may affect programmatic aspects of the program. For example, space hardware will be designed for a three-year mission life, the program should be low risk, and the development of additional international partnerships is encouraged. Thus, the GPM initiative reflects the influence of different requirements and constraints, including the science objectives, partnership arrangements, and programmatic constraints. The process by which these different factors have been amalgamated into the Program's Level One Performance Requirements is illustrated in Fig. 1.

A careful review of Fig. 1 shows the key aspects of the program. Observational measurements will be performed by two types of spacecraft, the primary spacecraft and constellation spacecraft. The primary spacecraft will manifest the NASDA-provided DPR and a multi-channel, conical scan microwave radiometer (the GPM Microwave Imager, or GMI). The DPR consists of two radars taking simultaneous measurements of the same atmospheric volume in the Ka-band and Ku-band of the microwave spectrum. The use of these radars together provides the capability to compute drop-size distributions (DSD) of rainfall. The Ka-band radar provides increased sensitivity (in comparison with the TRMM PR) for the measurement of light rain such as frequently found at the higher latitudes

(see Table 1 for additional information on the DPR). The GMI will have, as a minimum, the same capabilities as the TRMM Microwave Imager (TMI). Definition studies are currently in progress for this instrument, with additional capabilities under consideration, including the addition of high frequency measurement channels to provide increased sensitivity for the measurement of light rains, and increased aperture size to provide increased ground spatial resolution. See Table 2 for additional details concerning GMI's minimum complement of measurement channels. Equipped with both the DPR and GMI, the primary spacecraft will provide measurements of DSD, the three-dimensional structure of clouds, and well-calibrated measurements of precipitation. By comparing measurements from the DPR with measurements from the GMI, a standard will be established against which precipitation measurements made by other microwave radiometers may be calibrated.

TABLE 1
PROPOSED DPR KEY PARAMETERS

DPR	PR-U	PR-A
Antenna Size	2.4 x 2.4 x 0.5 m	1.0 x 1.0 x 0.5 m
Peak Power	1000 W	180 W
Frequencies	13.6 GHz	35.55 GHz
Sensitivity	17 dBZ	11 dBZ

TABLE 2
GMI MINIMUM PERFORMANCE REQUIREMENTS

Freq (GHz)	Stab (+/-) (MHz)	BW (MHz)	Pol	NEDT (K)
10.65	10	100	V	0.55
10.65	10	100	H	0.55
18.7	20	500	V	0.78
18.7	20	500	H	0.78
21.30	20	200	H	0.89
37.00	50	2000	V	0.77
37.00	50	2000	H	0.77
89.0	100	3000	V	1.12
89.0	100	3000	H	1.12

A. ABBREVIATIONS:
 Freq = Frequency BW = Bandwidth Pol = Polarization
 V = Vertical H = Horizontal
 NEDT = Noise Equivalent • Temperature = Radiometric sensitivity
 stab = stability = center frequency stability

GPM will rely upon a constellation of spacecraft to provide frequent measurements of precipitation on a global basis. NASA anticipates contributing, in addition to the primary spacecraft, one spacecraft to this constellation that will be equipped with the GMI. DMSP and NPOESS, other United States programs that will have microwave sensors flying during the GPM-era, will also provide precipitation measurements to GPM. In

addition, NASA is in advanced discussions with several foreign countries to contribute either a dedicated spacecraft for precipitation measurement, or the data streams containing rainfall measurements from satellites operated in conjunction with other programs.

Validation of the measurements from space will be performed, in part, through an inter-

comparison of measurements from the primary spacecraft with the measurements from the constellation spacecraft. In addition ground validation using regional rain gauge networks and several “Supersites” (ground validation sites equipped with radars, disdrometers, and rain gauges) will be used.[1]

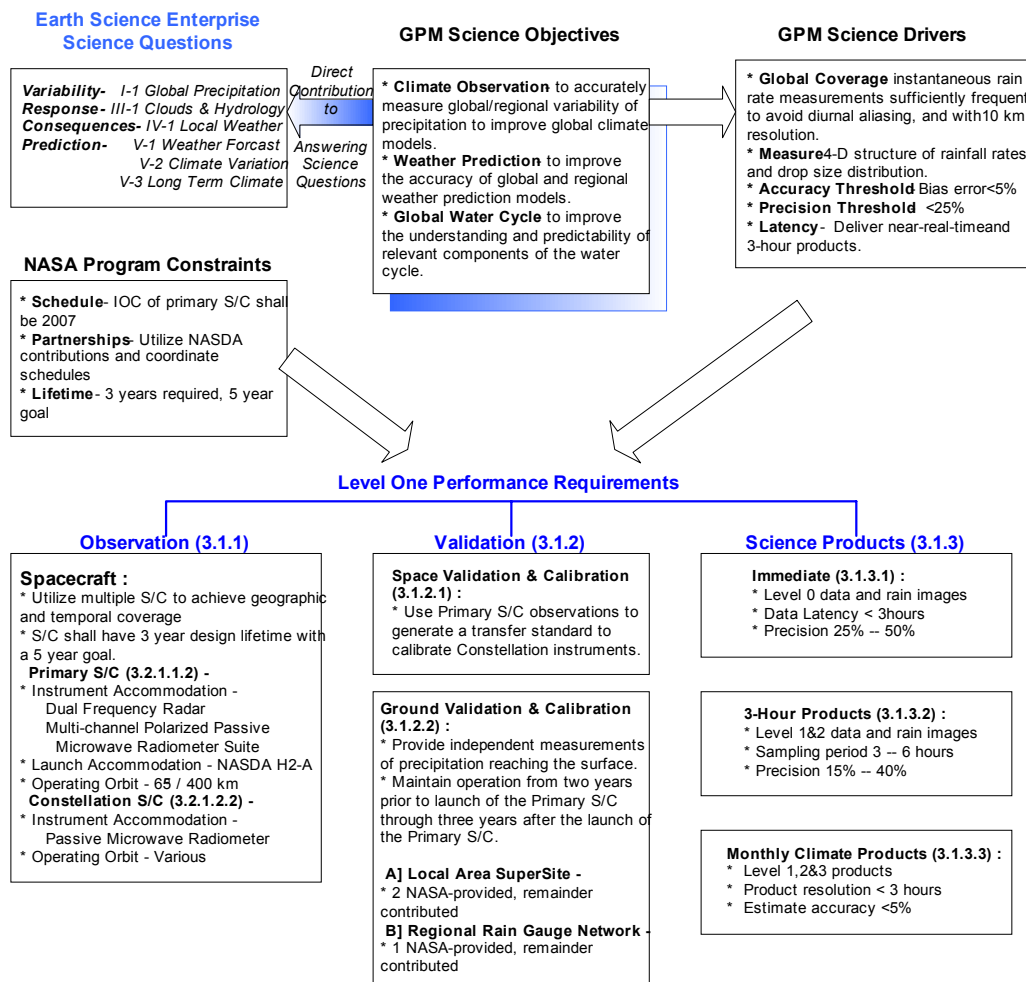


Fig. 1. GPM Requirements Traceability Overview

SUMMARY

The success of TRMM has provided strong support for the development of a successor mission which will address climate observation and prediction, weather prediction, and flood and fresh water resources. A Project Formulation Office has been established, the Level One Performance Requirements identified, and the methods to address those requirements proposed.

REFERENCES

- [1] S.W. Bidwell, et al, “Plans for Global Precipitation Measurement Ground Validation,” *IGARSS 2002*, in press